HISTORIC AMERICAN ENGINEERING RECORD

SEE MASTER PROJECT RECORD FOR CAPTION

HI-1

R.W. MEYER SUGAR MILL, 1878
NORTHEAST OF KUALAPUU OFF STATE ROUTE 47
(MOLOKAI, ISLAND of)
HAWAII & Maui County

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PHOTOGRAPHS

WRITTEN HISTORICAL AND DESCRIPTIVE DATA

Historic American Engineering Record
Heritage Conservation and Recreation Service
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HISTORIC AMERICAN ENGINEERING RECORD

R. W. MEYER SUGAR MILL

HAER HI-1

Location:	Northeast of Kualapuu off State Route 47
Date:	1878
Original Owner:	R. W. Meyer
Present Owner:	R. W. Meyer, Ltd.

Significance: The R. W. Meyer Sugar Mill is the only surviving 19th Century Hawaiian sugar mill with its original machinery intact and its original design essentially unaltered. Although the Meyer mill was among the smallest in operation during the 1888's, it exists today as a rare complex representing the early history of Hawaii's sugar industry.

Historian: Daniel Bluestone, 1978

Emigrating from Germany at the age of twenty-five, Rudolph Wilhelm Meyer arrived in Hawaii aboard the "Cheerful" on 20 January 1850.[1] In 1853, Meyer settled permanently on the Island of Molokai. He married Kalama Waha and raised his family at Kalae. Over the years Meyer held a number of appointments from the Royal Hawaiian government. Many of the appointments indirectly involved his early German training in surveying and civil engineering.[2] He served as Road Supervisor, Fence Commissioner, Appraiser of Homesteads, and he advised the Interior Department on such matters as bridge building and the construction of Molokai's Kalaeokalauu Lighthouse.[3] Meyer also served as Molokai's Postmaster, School Board member, District Magistrate, and Superintendent of the Board of Health's Leprosy Settlement. Reflecting on Meyer's public activity, a visitor to Molokai in 1885 wrote, "Mr. Meyer is in fact, if not in title, the Supreme official authority of the whole island . . . For his integrity, fidelity and good management, he is deservedly respected, honored and trusted by all."[4]

Despite his major public responsibilities, Meyer's public work simply supplemented the family's dominant activity in agriculture. Between 1852 and 1890 Meyer acquired 2,936 acres of land.[5] He used most of his land as pasturage for diary cows, cattle, oxen, and horses. He also raised chickens and pigs. Aside from overseeing his own ranch animals, Meyer managed the arid ranch lands on Molokai's west end. The ranch was owned successively by King Kamehameha V, Princess Ruth Keelikolani, and Bernice Pauaki and Charles Bishop. The Molokai Ranch which Meyer managed far exceeded his own holdings. In 1889, for example, the Molokai Ranch had 3,600, 70 horses,

and 12,000 sheep; Meyer's pastures had at this time 200 cattle, 24 oxen, and 63 horses.[6] Visiting Kalae in 1892, C.M. Hyde reported that Meyer ran one of the three agriculturally productive and "well-kept" places on Molokai. Hyde wrote that Meyer's development of his plantation has "given opportunity for the cultivation of a great variety of plants and trees . . .Mr. Meyer has tried the adaptability of various plants of commercial value."[7] Meyer planted with varying degrees of success coffee, corn, wheat, oats, taro, potatoes, beets, cassava, peaches, mangoes, bananas, and grapes.

For over a decade, between 1876 and 1889, as part of his diverse agricultural activities, Meyer cultivated sugar cane.[8] He also built a small sugar mill to process the cane into sugar and molasses. The R.W. Meyer Sugar Mill operated at a time when the Hawaiian sugar industry was rapidly expanding. The expansion had been effected in 1876 with the signing of the Reciprocity Treaty between the Hawaiian and American governments removing the tariff on Hawaiian sugar sold to the United States. Hawaiian sugar exports rose from 25,080,182 pounds in 1875 to 93,787,483 pounds in 1881.[9] The willingness of investors to invest capital in the Hawaiian sugar industry after the Reciprocity Treaty led to rapid modernization of old Hawaiian sugar mills and the introduction of many technical improvements in sugar cultivation, irrigation, and manufacture. Although Meyer built his mill during this period he did not really share in the Reciprocity Treaty-era expansion or technical innovation. Meyer instead built a small mill to handle the modest production of his family's plantation, supplementing the income derived from other agricultural and public activity. In nearly all of its major sugar manufacturing operations -- grinding, clarifying, evaporating, cooling, and drying -- Meyer adopted

and followed mill practice and used mill equipment more representative of the 1850s and 1860s than of the 1870s and 1880s. The mill and plantation system thus repeated an earlier technical and agricultural period in the growth of the Hawaiian sugar industry.

In October, 1883, the Auditor-General of the Hawaiian government compiled a list of the value of each sugar plantation and mill operating in Hawaii. The $10,000 value of the Meyer Plantation and Mill made it the smallest sugar operation in Hawaii; the next smallest mill was valued at $50,000. Of the fifty-six Hawaiian sugar operations in 1883 only six, including the R.W. Meyer operation, were valued at less than $100,000. The average value of an Hawaiian sugar operation at this time was $284,000.[10]

It is surprising that despite its small size and relatively short period of operation, the Meyer Mill exists today (1978) as Hawaii's most complete and informative site for observing a nineteenth-century Hawaiian sugar mill. It is, perhaps, because of its small size and brief operation that the mill remains intact. The mill did not modernize. It did not throw away machinery and did not operate on an island with an active scrap market. The mill also has remained in the ownership of the Meyer family since it was built. The relatively simple machinery originally installed by Meyer could have not been sold second-hand in Hawaii in the 1880s because the other sugar mills were technically more advanced and required completely different styles of equipment to carry out their own sugar manufacturing.

In 1880 George Bowser reported in his Statistical and Commercial Directory that Meyer cultivated 27 acres of cane and anticipated a yield of 50 tons. Bowser did not report how many acres of cane were to be harvested for this crop. Bowser reported that with 27 acres planted Meyer

"intends increasing the area yearly, in cultivation of sugar cane."[11] Despite Meyer's planned expansion, the area under cultivation in September, 1885, totalled only about 30 acres.[12]

In many ways the geographical position and contours of Meyers's land restricted the size of his cane fields. Meyer apparently could not grow all of his sugar cane in one area -- the plantation was broken up into four main units. Cane grew in Puahaka, Kaihohanu, and Kahakaimanamana valleys and on scattered flats across the sloping lands overlooking the valleys adjacent to the house and mill.[13] The valleys, which protected the cane from the area's high winds, were all quite narrow and cane grew on their sides and floors. The separate and fragmented areas for cane cultivation divided the plantation into separate agricultural units. The plowing, planting, cleaning, and harvesting of cane could not easily be coordinated; the different areas frequently grew under quite distinct agricultural schedules. Cultivating at least four different varieties of cane -- Kenikeni, Manulele, Ohia, and Kakona Kana -- Meyer adapted these varieties to the different sections of the plantation.[14] In January, 1883, managing the sugar plantation in his father's absence, Otto S. Meyer wrote, "The cane of [Kaha] Kaimanamana I think is going to die, about 3/4 acre is all dry, I do not know what the reason is I think it is too cold up here for Kenikeni."[15] In April, 1883, continuing to adjust the suitable cane varieties for the separate fields, Otto Meyer wrote, "I think it will be better to have Kenikeni on that 7 acre field -- and that little piece below the peaches -- about 3 acres must have Kenikeni also except Puahaka Makai I think it will be better for Manulele & Ohia cane there."[16] The small quantities of each variety of cane, necessitated in part because of the

lack of uniformity in the Meyer cane lands, caused some inconvenience because the varieties were processed separately. In May, 1883, Meyer wrote, "We have not enough Kenikeni to grind one day, but I will try to grind the Kenikeni without mixing [it] with the Manulele."[17]

An 1881 report on the sugar industry in Hawaii outlined some additional difficulties that fragmented cane lands such as Meyer's might have caused. The report stated, "upland flats are generally so narrow that one compact unbroken piece of land, large enough for a plantation, seldom occurs. It is a matter of extreme inconvenience to a planter to have his farm cut up into three or four pieces by gorges 300 to 500 feet deep, which are very difficult to cross, and if the component tracts are too small, his farm will not pay."[18] Another difficulty Meyer had in raising sugar cane was the unpredictable and variable weather in Kalae. The cane depended on rainfall which at times was insufficient.[19] The lack of water had imposed limitations on agriculture in Kalae since Meyer first settled there. Originally Meyer brought water by hand from a spring a mile from his land; he then brought it on horseback. Later a rainwater cistern was used to collect water and in 1876 Meyer laid down a pipe to bring water to his land.[20] The piped water reportedly improved cultivation at Kalae;[21] however, it did not serve as the basis for sugar cane irrigation. Irrigation required more water, more investment, and probably would have been inefficient given the small dispersed tracts of cane land. In 1883, Meyer did water, probably by hand, same "newly planted cane" during the drought.[22]

No systematic account of the annual yield of sugar cane on the Meyer Plantation survives. Figures available for 1883 indicate that in terms of sugar cane yield per acre, the Meyer Plantation produced near the average for other Hawaiian cane plantations. In 1882 Planters' Monthly, the

agricultural journal representing Hawaiian sugar planters' interests, reported the average sugar cane yield in Hawaiian fields was about three and one-half tons per acre for plant cane and two tons per acre for rattoon cane.[23] In May, 1883, suggesting a general pattern of higher yields, Meyer wrote, "We have commenced [cutting] Makai [Ocean] side of Kaihohana now there is not much cane there I think it will be a little over two tons per acre."[24] Indeed, a week earlier cane harvested from the Mauka (Mountain) side of Kaihohana yielded a little more than three tons per acre.[25] Meyer estimated a more disappointing yield in June, 1884, when he wrote that a 1.5 acre plot in Puahaka Valley was expected to yield only one ton.[26]

Sugar cane in all stages of development grew on the Meyer Plantation at any one time. The field work alternated between plowing, planting, cleaning of the leaves, cutting, and replanting. After the cane was cut it was loaded onto a cart and pulled by oxen from the field to the sugar mill for manufacture into sugar. The basic manufacturing process is to express, generally through pressure, the cane juice. By boiling, the high proportion of water in the cane juice evaporates, leaving behind sugar crystals. Finally, the raw sugar is separated from its by-product, molasses. This process was followed in the Meyer Mill and most other sugar mills. Regardless of the level and state of the processing technology, the object of raw sugar manufacture is to separate the cane juice from the cane and the sugar crystals from the juice and molasses.

Meyer placed the cane mill on a small rise located forty feet south of the Boiling House. Manufactured by Edwin Maw of Liverpool, England, the mill could grind one ton of cae in a ten-hour day.[27] The mill consisted of one set of three horizontal rolls, each 15" in diameter and 22" long.

Large timbers served as the mill's bed plate; they supported the mill on a rock foundation covered with a Portland Cement plaster. The timber bed plate absorbed the mill's vibration and cushioned the shock of an excessive load passed through the mill; hydraulic jacks in later mills performed this same function.[28] The mill was located in the middle of an 18' in diameter, 6' deep, circular masonry enclosure, excavated into a small mound. A masonry-lined passageway led in one side and out the otherside of the mill's masonry enclosure. The cane was probably either carried or brought by cart into the mill area from the east side; the "bagasse," cane residue left after grinding, was then carried out the west side. The mill appears originally to have had a cane feed tray on the west side and a bagasse receiving tray on the east side. The feeed tray allowed the mill operator to arrange cane along the whole length of the roll -- permitting an efficient, regular, and even feed and crushing of the cane.[29] The bagasse tray received the cane as it passed out of the mill.

The cane was fed between the top roll and the first of the lower rolls; a small guide in the middle of all three rolls then deflected the cane back up between the second lower roll and the top roll. As the cane passed through the mill, expressed juice flowed into the juice tray beneath the bottom rolls where it was funneled through a small opening into an open gutter. The open gutter carried the juice downhill through a short tunnel in the masonry enclosure surrounding the mill to the Boiling House for further processing.[30] During a ten-hour day, when the mill operated to capacity and processed one ton of sugar cane, approximately 2,200 gallons of cane juice passed from the mill's juice tray to the Boiling House.[31]

Animals provided the motive power for the Meyer cane mill. The 18' diameter, 6' deep, circular masonry enclosure was constructed primarily

to permit animals to power the mill from the mound above without interfering with the activity of feeding the cane mill itself. Wooden bridges permitted the animals to cross over the top of the two passageways leading to the center of the mill area. The mill's vertical drive shaft rose above the edge of the masonry enclosure; four mill animals could circle the mound harnessed to booms which radiated about 15.5' from the drive shaft. Meyer apparently employed mules, horses, and oxen to power his mill during various periods of its operation.[32] A set of bevel gears transmitted the animals' circular movement around the mill's drive shaft to the shaft of the top roll. The top roll in turn moved the bottom rolls through a set of spur gears located on the side of the mill opposite the drive shaft.

The vertical drive shaft's bevel gear wheel had 22 teeth while the bevel gear wheel connected to the top roll carried only 17 teeth; this arrangement meant that in slightly less than one full circuit by the animals, the mill rolls made a complete revolution. Traveling in a circle approximately 15.5' from the drive shaft, the mill animals traveled about 86.5' around a 98' circuit to impart one full revolution to the mill rolls. Theories concerning the proper speed of the mill "to insure time for the cane to be perfectly crushed" and to permit time for juice to drain in the center of the mill varied during the nineteenth century. Estimates generally ranged from 15' to 20' per minute at the periphery of each roll.[33] In order to operated the mill within this range of speed the animals powering the Meyer mill would have had to circled the mill at a speed of 3° to 4 miles per hour.[34]

Among 1880s Hawaiian sugar mills, Meyer's probably was the only one powered by animals. During the 1850s, Hawaiian planters began turning from animals to steam and water as a source of motive power for cane mills. In

1853, apparently troubled by the periodic inadequacy of water for its Patent Water-Wheel driven mill, the Lihue Plantation on the Island of Kauai purchased the first two steam engines to operate in Hawaii, one of 24 horsepower and the other of 6.[35]

The failure to properly identify the specific part of the sugar manufacturing process using steam has produced a series of conflicting nineteenth-century accounts on the prevalence of certain forms of sugar mill motive power. Thomas Thrum reported that of the 22 plantations operated in 1861, 12 were powered by water, 9 by steam, and one by animal power.[36] In 1866, Henry M. Whitney reported 33 mills in operation; 19 driven by water, 5 by steam, and 9 by horse or mule power.[37] In the following year, Gerrit P. Judd surveyed and compiles statistics on 31 of 35 sugar plantations operating in Hawaii. Judd's figures record even more strongly the dominance of steam and water power: 21 plantations used some steam power; 17 used some water power; and only two reported the use of any animal power.[38] During the 1870s, cattle-powered mills were still manufactured; however, in the face of steam and water power developments, they were generally not held in high regard. The English periodical Sugar Cane reported in 1871, "cattle mills, though still made in considerable numbers for some few parts of the world, are quite incapable to compete with the larger and more efficient mills driven by steam, and are only employed by those manufacturing on a very small scale indeed."[39] The Meyer family's 30 acres of cane fields certainly could be classified in 1876 as a "small scale" operation. In 1857, reflecting the growing popular favor of steam, a sugar technologist wrote, "Of animal power I shall not speak, as no one is likely to defend such a rude and barbarous process, and which can never be rendered so economical as steam. The steam engine is far superior to any other motive power in economy, force, regularity of action, independence

of all local influences which affect other motions, the perfect control under which it can be maintained."[40]

Meyer's modest-size sugar plantation, and abundant animal power available on his ranch made the choice of an animal-powered mill a reasonable one even in the face of the nearly complete dominance of steam and water power development throughout the industry. Sufficient water was not available at Kalae for water power. By not joining in the transition from animal to steam power, Meyer availed himself of considerable savings -- he did not buy a steam engine to power the mill and the mill he purchased may well have been very inexpensive and second-hand. The mill Meyer installed in 187 may have been manufactured 10 to 20 years earlier.[41]

In March, 1877, the Blymyer Manufacturing Company of Cincinnatti, Ohio, provided Meyer with an estimate for the cost of installing a steam-powered mill of the same capacity as the animal-powered mill he eventually purchased.[42] The price for a "No. 4 Mill" was $1,500, and for a 16 horsepower, 8"x16", horizontal steam engine with a boiler, $1,090. Blymer offered a discount to Meyer as part of its entry into the Hawaiian market, and the total cost for the mill and engine was $2,385. The Edwin Maw mill purchased by Meyer cost between $400 and $925. In 1879 Meyer purchased a small steam engine and boiler for $625 to power the Mill's centrifugals which would have been powered by Blymer's 16 horsepower engine if he had purchased the Blymyer mill. To obtain an animal-powered mill and power for his centrifugals, Meyer paid between $1,025 and $1,550 as opposed to $2,385 for the Blymyer steam-powered mill and power for the centrifugals.[43] This price difference amounted to at least eleven percent of Meyer's initial $7,382 investment in the mill, or even more depending on the actual price paid for the sugar mill.[44] In short, given the ready availability of mill animals on Meyer's ranch, a crop well

within the capacity of an animal-powered mill, and accessible second-hand sugar mills, Meyer undoubtedly saved money by adopting an animal-powered mill rather than employing steam.

Prior to the 1882 installation of a five-roll mill at the Hawaiian Commercial Company mill on the Island of Maui, nearly all mills in Hawaii were of the basic three-roll, horizontal type with two iron rolls set below and one above -- similar to the Meyer Mill.[45] The size of the rolls varied greatly, and was in part determined on the available motive power. Mills with larger rolls had a greater capacity because more cane could be fed through at one time; they also required more power to keep them in motion. The 15" diameter and 22" length of the rolls on the Meyer mill reflected the limited power available from animals. Much larger rolls with greater capacity operated twenty-five years earlier than the Meyer Mill. In 1857 the Pacific Commercial Advertiser reported that the Hawaiian mills in operation generally had rolls 24" in diameter and 48" long.[46]

In 1851, the Wood and Spencer Plantation and the Lihue Plantation both operated three-roll mills, with rolls 26"x54"; however, they required water power to turn the rolls, which weighed about 3 tons each.[47] The mill with 3-ton rolls could not have been turned easily by animals. In 1878, the Heeis Plantation at Koolaupoka on the Island of Oahu installed a mill with a capacity to grind ten tons of cane per day, ten times greater than the Meyer capacity; the Heeis mill required a 100 horsepower steam engine to operate the rolls.[48] The rolls on the Hawaiian Commercial Company's 1882 five-roll mill measured 32"x66" in the three-roll stand and 36"x66" in the two-roll stand.[49] The largest mill operated in Hawaii during the period of the Meyers put their 15"x22" mill in operation was at the Hawaiian Agricultural Sugar Mill and Plantation Company. With a capacity of 20 tons

per 10-hour day, the mill's 12-ton, 36"x78" rolls required two 21"x24" horizontal steam engines for power.[50]

After cane juice was expressed from the sugar cane it had to be quickly boiled to arrest fermentation and neutralize the acid in the juice.[51] Once the cane was brought to its initial boil it was continuously exposed to heat, evaporating the water from the juice, and concentrating the sugar crystals into a thick syrup. At the Meyer Mill, the juice flowed downhill in the open gutter to the Boiling House where it flowed into two copper clarifiers. John Nott & Co., a Honolulu copper and tinsmithing company, manufactured the two copper clarifiers for the Meyer Mill in December, 1878; they cost $340.[52] The two clarifiers occupied the east end of the 39' long, 5' wide boiling range and flue where all the clarification, evaporation, and concentration of the cane juice took place in open pans over the continuous flue leading from the Boiling House's furnace. The clarifiers were set just above the furnace end of the range and received the most direct and intense heat. Wood, and probably some bagasse from the cane mill, was stoked through a furnace door on the outside of the Boiling House's east wall.[53] Honolulu Iron Works manufactured the furnace door for $15.36 in March, 1879. Iron grate bars supported the furnace charge. In the clarifiers, lime was added to the cane juice so that impurities would coagulate into a thick scum on top of the near-boiling juice. Cracks in the surface scum indicated the completion of initial clarifying. The clarified juice was then drained through a cock in the clarifier into the sorghum pan for evaporation and concentration.

John Nott & Co., of Honolulu, also manufactured the sorghum pan which was ordered in two sections at a total cost of $770.[54] The sorghum pan had an overall length of 30' and a width of 5'. The pan had a riveted bottom built up of 4'x6' sheets of copper. The sorghum pan was set securely into

passed through the pan.[59]

In 1883, Otto S. Meyer wrote to his father about sorphum pan boiling practice: "I think what Una said was right about boiling the sugar, putting in only 4 inches at a time inside the container, and so on, until the containers are full. It's certainly true that having a lot in the container is the reason the sugar darkens because of the high heat inside the container, and that probably is the basis of the molasses. I will try boiling the sugar in the way Una told me, putting in a little bit, until it is cooked to 91 degrees. Maybe that's the way to increase the "maka" of sugar. I'll try and see."[60] By maintaining the level of the cane juice at four inches or higher, Meyer substantially altered the process for which the sorphum pan was initially designed. The 2.5" high, 4' long, metal fins riveted to, and projecting upwards from the base of the sorghum pan were initially designed to impart a circuitous route to the juice flowing through the pan. When the juice level was lower than the projecting fins it passed over the greatest possible heating surface. In a 12'x6' sorghum pan with twenty fins, for example, free-flowing cane juice passed over 96 feet of heating surface in passing from one end to the other.[61]

The sorghum pan process of evaporating and concentrating cane juice served as an important transitional step in Hawaii between the open-fire, open-kettle, boiling of cane juice and the later steam-boiled process operating in closed heaters, vacuum pans, and evaporators. In March, 1863, Charles Cooke and Harvey Davis sailed to Honolulu from San Francisco bringing with them the first sorghum pan used in Hawaii. Initially doubting the adptability of an American sorghum syrup manufacturing process to the manufacture of sugar, Hawaiian planters treated the sorghum pan skeptically.

the firebrick, asonry, and Portland Cement flue range. Redwood planks screwed into the upturned edges of the sorghum pan's copper bottom formed both the pan's 24" sides and the partition walls between the pan's five separate compartments, and kept boiling juice from splattering out of the pan.[55] Hot gasses moving through the flue from the furnace at one end of the boiling range to the smokestack at the other end heated the entire bottom surface of the sorghum pan. Honolulu Iron Works manufactured the smokestack for $200 in 1879.

The sorghum pan had a flat, continuous bottom; however, the setting of the pan on a descending slope from the east (furnace) end of the range to the west (smokestack) end permitted the cane juice to flow by gravity from one compartment to the next. Hand-levered sluice valves in the partition walls permitted the sugar boiler to regulate the movement of batches of cane juice through the pan. The long sorghum pan, divided into compartments, facilitated the continuous grinding of the sugar cane by allowing different batches of cane juice, in different stages of concentration, to flow through the same pan, over the same continuous flue, at the same time. As water evaporated from the cane juice, the density of the juice increased; the potential for spoiling the sugar by boiling it too long and burning it frequently, also increased as the sugar flowed through the pan. Frequently, an in or two of juice maintained in the pan prevented burning or discoloring.[56] Using a scarometer and a thermometer, the sugar boiler monitored and guided the density and the temperature of the cane juice.[57] Meyer used wire and fabric cloth to filter impurities from the cane juice, probably as it left the mill's juice tray and as it flowed from the clarifier into the sorghum pan.[58] Wooden skimmers were also used to remove impurities that coagulated as the cane juice

In April, 1863, the J.H. Wood Plantation in Nuuanu, Island of Oahu, installed the 12'x4' sorghum pan and it operated impressively.[62] A newspaper reported the sorphum pan's success: "it was found that not only the finest of syrup could be made but that sugar of the best quality could as easily be produced. For the past few weeks the plantation has been turning out the very best of sugar, and with a rapidity almost marvelous . . . creating a furore . . . which we may compare to the periodical gold fevers in California."[63] The major advantage of the sorghum pan over the dominant method of open-kettle boiling was the speed with which manufacture could be effected: "The juice passes through the boiler so quickly, [20-30 minutes], as to prevent in a great degree it becoming acidified, and consequently reduces the amount of molasses obtained."[64]

The early perception of the sorghum-pan process was that it was ideally suited to the sugar mill operated on a small scale; it increased the chance for making very high-grade sugar by a "most astonishingly simplified and expedited" process, requiring only a small capital investment. The improvement thus favored any person, like R.W. Meyer, who "possessing from ten to twenty acres and a small capital [could] engage successfully in the manufacture of this great staple."[65] Several Hawaiian plantations quickly turned to the sorghum-pan boiling method in the 1860s -- larger pans appeared limited only by the size at which the flue could provide uniform heat. James Louzada had a 24'x8' pan installed on his Waikapu Plantation.[66] Judd, Wilder and Judd Co. were caught up in the sorghum pan enthusiasm as they planned their small Kualoa Plantation on the Island of Oahu. In January, 1864, they attempted to have the "sorghum pan man from California" install a 40'x12' pan in their new mill.[67] In March, 1864 R.P. Judd wrote his partner, S.G. Wilder, "Sorghum Pan -- This

is all the rage here now. Henry talks of putting up one at Wailuku. Needham has told me today his works admirably. He gave it a different pitch and now it is good for 1 ton a day. John Wood is doing better. The Kauai men have sent 2 lots [of] splendid sugar -- make 1 1/2 tons a day -- John Wood's man says ours ought to work well it is so long."[68] The first pans set up on the islands lacked the partitions found in the Meyer's pan; however, the partitions had been introduced in the United States in 1862 as "Cook's Evaporator with Cory's Improvement . . . in such a manner that the circulation of the evaporating fluid can be detained or regulated at pleasure."[69] Another important change effected in the pan by the time Meyer installed one was that they were produced locally and not imported. John Nott & Co., of Honolulu, who started producing the pans in the late 1860s, installed Meyer's pan in the late 1870s.[70]

Building their Kualoa Mill at the time that sorghum pans were introduced in Hawaii, Judd, Wilder and Judd Co. had already considered manufacturing sugar using the older method of sugar boiling. They initially planned to install the traditional system of completely separate sugar pans or kettles set into a continuous flue. The five pans decreased in size reflecting the smaller amounts of cane juice left as evaporation proceeded -- their size ranged from 84" in diameter and 26" deep down to 56" in diameter and 21" deep.[71] The pans required a rather laborious process of ladling the sugar from one pan to the next.[72] The slow ladling of sugar between the pans frequently injured the quality of the sugar due to excessive boiling.[73] Some sugar kettles incorporated rains and cocks and were set on a sloping range to take advantage of gravity flow to move the juice from kettle to kettle.[74] Even after the cocks and valves made ladling unnecessary, the flat bottom evaporator, like the sorghum pan, offered further advantages. With the pan set over the

entire flue the heating surface increased, less fuel was required for evaporation, and a batch of cane juice could be concentrated more rapidly, reducing the chance of burning it.[75]

The "rage" and "furore" which greeted the 1863 introduction of sorghum sugar pans in Hawaii promoted the replacement of the older boiling pans and kettles by the sorghum pan or rectangular evaporator; however, the popularity of sorghum pans was soon eclipsed by the increased use of steam heat for evaporating the cane juice. In 1857 a Honolulu newspaper reported, "Louisiana is indebted for the superior quality of her sugars to the improved process of manufacture, in steam trains and vacuum pans. At the Hawaiian Islands, the more primitive method of manufacture has been the only available one, in open kettles over the open fires."[76] The same newspaper reported a change in these "primitive" conditions just a few months later when Lihue Plantation imported an $800 steam-heated evaporator "calculated greatly to facilitate the sugar boiling process."[77] The steam boiling of sugar permitted even greater regulation and control over the boiling juice. Formerly the sugar boiler had to counter the variables of the furnace draft and the heat of an open fire; with steam the heat could be turned on and off at just the right moment permitting more precise control of temperature -- reducing further the possibility of burning the sugar.[78]

Steam boiling first took the form of open-pan boiling -- steam pipes were introduced into pans very much like the sorghum pan and the boiling method remained essentially the same, simply relying on steam heat rather than an open fire. In 1867, of the thirty-one plantations for which G.P. Judd collected statistics, six plantations employes steam "wholly or in part" for evaporation.[79] Many other improvements in Hawaiian steam evaporation followed in the two decades after its 1857 introduction on the Lihue Plantation. Vacuum pans facilitated the boiling of sugar <u>in vacu</u> at very low temperatures,

producing a higher quality sugar than possible from boiling at higher temperatures at atmospheric pressure. The move to evaporation in closed containers permitted the recycling of steam vapor for use in further evaporation -- at a great savings in fuel and boiler construction. During the transition period from fire to steam evaporation and concentration, plantations frequently employed both forms of heat at different stages in sugar manufacture. The Judd, Wilder and Judd Co. plantation at Kualoa for example, ran the cane juice through steam clarifiers, open-fire evaporators, and a copper worm steam pan for concentration.[80]

Despite the widespread application of steam for boiling on other sugar plantations throughout Hawaii during the 1870s, R.W. Meyer did not use steam for any part of the boiling process; instead, he installed the sorghum pan which represented the best available method of open-fire sugar manufacture. Depending on the initial density of the cane juice and the temperature of the furnace and flue, it probably took about one hour for cane juice to pass from the clarifier, through the sorghum pan, to the last smallest compartment, called the strike or teach, where the sugar boiler had to artfully decide the proper moment to open the final sluice valve, located on the side of the final compartment, and permit the properly concentrated syrup to run out of the pan.[81]

After the concentrated syrup flowed out of the sorghum pan, in the "strike", it cooled and crystallized in large iron sugar coolers.[82] The Meyers could have drained the sytrup in a gutter from the sorghum pan to the coolers; however, they apparently carried the syrup by hand. In 1883 Otto S. Meyer wrote his father in Honolulu asking him to order "1 square box of galvanized iron for carrying the juice, 36x36 and 14 inches high."[83] A pan of this size, carried by two people, could have held an entire strike from the sorghum pan.

Sugar coolers were five to ten feet long, three to five feet wide, and one to one-half feet deep.[84] The Meyer Mill started operation with four iron coolers purchased from C. Brewer & Co. for $45 each. Two more coolers were added in 1880, and in 1881 Meyer bought six more sugar coolers costing $40 each. The coolers purchased in 1881 came at the same time the shed along the north wall of the Boiling House was rebuilt and expanded. The humidity and vapors given off by the clarifiers and evaporator would have retarded the crystallizing and cooling of the sugar in the Boiling House;[85] the adjacent shed appears to have served as the Sugar Cooling Shed.

The twelve iron sugar coolers purchased for the Meyer Mill between 1878 and 1881 are no longer in the Mill. Two galvanized iron pans 6'7"x5'7 1/2"xl'7 1/2" are still on the site and may have been used as sugar coolers prior to their most recent use as pans for soaking coffee beans. A sheet of metal supported between two pieces of lumber formed a 11'7"x6'1.5" table which stood in the Engine and Boiler House and may also have served as a crude homemade sugar cooler; however, it clearly is not one of the more substantial iron coolers purchased for the Mill and costing between $35 and $45.[86] The large number of sugar coolers purchased for the Mill kept the different varieties of sugar separate as they cooled and awaited further processing.

After sugar was granulated and cooled it was dried and drained in centrifugations which completely separated the sugar crystals from the molasses. Each centrifugal consisted of two baskets -- an outer stationary basket 33" in diameter and 16" deep, and an inner moving basket 30" in diameter and 10" deep. Operating very much like a modern washing machine on the spin cycle, the centrifugals' inner baskets revolved at approximately 1,200 revolutions per minute creating a centrifugals force in the basket. The liquid molasses flew outwards through the perforated sides of the revolving basket into the

fixed outer basket; dried sugar crystals were left behind in the inner basket. Depending on the size of the charge and the degree of its granulation the separation could be effected in a matter of minutes. The molasses flowed out a spout in the bottom of the fixed basket and into one of four Molasses pits beneath the Boiling House floor. The pits were linesd with cement plaster and measured 71.5" wide, 72" deep, and had lengths of 12'9", 4'10", 5'7", and 5'11". The sugar was shoveled by hand out of the inner basket and put into bags for shipping.[87]

The centrifugals were driven by a 4" belt connected to the countershaft of a small steam engine. The belt ran from the small pulley at the base of the centrifugal's revolving basket to the loose and fast pulleys on the steam engine's countershaft. A wood clutch connected to a sliding wood belt-guide made it possible to turn the centrifugals on and off by guiding the belt onto either the countershaft's fast, spinning pulley, or loose, motionless, pulley. Each centrifugal had its own separate clutch and pulley set. The belt required a half-turn in order to connect the vertical pulleys on the countershaft with the horizontal pulley on the centrifugal.

The centrifugals were made of cast iron and set on a cast iron and wood bed plate and a substantial masonry and Portland Cement foundation. The foundations had to sustain the shocks and vibrations arising from the machines' 1,200 revolutions per minute. The side of the interior basket was made of brass with hundreds of small openings to permit the molasses to fly outward. Metal rods, just outside of the basket lining, connected the top and the bottom of the interior basket and kept the brass lining in place. The basket turned on an overhanging bearing at the top of the stationary central spindle which extended from the centrifugal's bed plate, through the center of the basket's pulley and stem, to the top of the centrifugal. The central spindle

carried a master bolt which locked the revolving basket, the bearing, and the spindle together.

Although it lagged behind other sugar-producing areas in adopting some technical innovations, such as steam-powered mills and steam evaporators, Hawaii operated some of the earliest sugar centrifugals. The principle of centrifugal separation had already been applied extensively in the textile industry. Cotton and woolen goods, especially after being dyed, were dried in "hydro-extractors," the water flow outwards, like the molasses, and the dried textiles remained in the interior basket.[88]

David McCoy Weston of Boston, Massachusetts generally receives credit for applying, in 1850, the principle of centrifugal separation to the drying of sugar. Hawaiian boosters and historians have always claimed David M. Weston and the centrigual as their own. In 1895, for example, Henry Martyn Whitney wrote that a fact "showing the ingenuity and skill of mechancis in Hawaii" was that "the well-known centrifugal machine, now used in every first-class sugar factory throughout the world, had its origin in Honolulu, and was first used in Hawaiian mills for drying sugar. Mr. David M. Weston, its inventor, was a machinist who had a shop and foundry in Honolulu."[89] Contemporary sources do not support the Hawaiian origin of centrifugals or even Weston's residence in Honolulu at the time of their invention. In August, 1851, H.A. Peirce and Co., of Honolulu, wrote to the Royal Hawaiian Agricultural Society concerning "an invention for purging sugar, recently brought into use in the West Indies and now being introduced here . . . It is called the 'centrifugal separator' and consists of a perforated cask into which the sugar is thrown and by very rapid revolutions the molasses is forced out through the sides of the cast very rapidly, leaving the sugar clean and dry . . . Several of the machines have been ordered of Mr. D.M.

Weston, a practical machinist now in Honolulu, who came out from the U.S. for the purpose of setting up our sugar mill."[90] After setting up the Peirce mill and taking orders for centrifugals, Weston returned to the United States. On May 10, 1853, he returned to Honolulu and two weeks later was authorized by the Privy Council and the Minister of the Interior to lease the "Old Blacksmith's Shop" formerly occupied by the company of Knott & Jones.[91] The President of the Royal Hawaiian Agricultural Society lauded Weston's return to Hawaii and declared, "Our planters are to be congratulated on the return of Mr. Weston to the Islands, a man eminently qualified to improve our machinery and secure us against those vexatious breakdowns of mills, etc ..."[92]

Weston did not have a foundry in Honolulu at the time he adapted the centrifugal separator to sugar manufacture, and he appears to have first introduced the idea in the West Indies and not in Hawaii. However, Weston's presence and his operation of a foundry in Honolulu from 1853-1860 helped guide Hawaii's early transition from drip separation to centrifugal separation. Prior to the intorduction of the centrifugal, the sugar removed from the coolers was placed in vats, boxes, or hogsheads. After two to six weeks when plugged drain holes were opened the molasses would separate from the sugar and drain from the containers. This process was rapidly eclipsed by centrifugals and the lengthy process of separation was carried out in a few minutes. In 1857, reporting on agriculture in Hawaii, a Honolulu newspaper declared, "Instead of hogsheads, the centrifugal separators, recently introduced, are preferred for draining the sugars."[93]

The first Hawaiian centrifugals set up by Weston operated by hand.[94] In 1853, Weston installed at Lihue Plantation the first two steam engines to operate on a Hawaiian sugar plantation. The smaller 6 horsepower engine operated centrifugals.[95] Unlike the centrifugals used in the Meyer Mill, Weston's centrifugals were driven from above, overdriven as opposed to under-

driven. When Weston sold his foundry to Thomas Hughes and Jamin, Green, & Co., in 1860, and left Hawaii, he apparently departed with the manufacturing rights to his centrifugals. The foundry, under the management of Alexander Young and the ownership of Theo. H. Davies & Co., incorporated in 1875 as the Honolulu Iron Works Co.. Honolulu Iron Works claimed Weston as its founder but the company never manufactured centrifugals and continued to provide Weston centrifugals only by importing them from either Weston's plant in Boston, later the American Machine & Tool Company, or from Mirrless, Tait & Watson, a British firm which carried the manufacture and patent rights to Weston's invention.[96]

At the time Meyer purchased and installed centrifugals at his Mill, Weston's Patent Centrifugal dominated the Hawaiian sugar industry. Weston challenged other manufacturers in patent battles. In 1880, for example, Weston wrote to Castle & Cooke demanding that they take some action to enjoin Claus Spreckles from importing eight Hepworth Centrifugals because they were being challenged in the U.S. Courts as "infringements on my machine."[97] Despite the patent battles and the relative dominance of the Weston Centrifugal, Meyer purchased centrifugals manufactured by another company. By the 1870s, many different forms, styles, and makes of centrifugals existed.[98] Honolulu Iron Works supplied Meyer with his first centrifugal in 1879 for $300 and his second centrifugal was purchased in 1881 for $350. The centrifugals did not incorporate many of the improvements contained in the Weston Patent Centrifugal. They required hand-shoveling of the sugar from the basket after drying, whereas Weston had patented a discharge valve which let the sugar drop directly into sugar bags or storage through gravity. The Meyer Mill centrifugals were underdriven and thus could not accommodate a bearing at either end of the driving spindle. The underdrive centrifugal, with its one overhanding bearing, required a heavier spindle and more energy to drive it

than the overdriven model.[99] In 1867, Weston patented the unloading valve as part of his overdriven centrifugal -- these patented imrpovements accounted, in large part, for the dominance of Weston's machine throughout the Hawaiian sugar industry. The Weston centrifugal was by no means the only type available in Hawaii, nor was it the least expensive. In fact in the 1870s a debate still existed within the industry as to whether overdrive centrifugals were preferable to underdrive. In 1881, when Meyer paid Honolulu Iron Works $350 for a centrifugal, the cost of a Weston's Patent Centrifugal supplied by the Honolulu Iron Works exceeded $1,000.[100] The Meyer Mill clearly could operate satisfactorily with the older style of centrifugal because the Mill did not process sugar continuously or require high sugar handling efficiency.

A steam pipe extending from the steam boiler to the area above the centrifugals may have provided some steam to the centrifugals. In the 1870s, steam was sometimes used to heat the molasses to dilute it and give it increased fluidity.[101] In 1864 G.P. Judd reported some other possible uses for steam in the centrifugal. He wrote, "I saw at the Rifinery [sic] today a new wrinkle. They threw in back of the centrifugals a current of steam to clean them while empty and in slow motion . . . The man syas they think of having a steam pipe with a universal joint to throw steam into the sugar while in the centrifugal to bleach it."[102] Steam at the Meyer Mill may also have been used occasionally to clean the molasses pits.

The two centrifugals at the Meyer Mill lack indentification and manufacturers' imprints of any kind and their origin remains unclear. Although Meyer purchased the centrifugals from Honolulu Iron Works, it is extremely unlikely that they were manufactured in Hawaii. In 1864, Judd, Wilder and Judd Co., transferred two centrifugals of nearly identical style from their

plantation on the Island of Maui to their new plantation at Kualoa on the Island of Oahu.[103] The design of the Meyer centrifugals can be assumed to date back to the early 1860s and, perhaps, even the 1850s. In 1934 T.T. Waterman, the Hawaiian Territory archivist, identified the centrifugals at Kualoa as possibly French in their design.[104] The overdrive centrifugal eventually eclipsed the underdrive centrifugal, such as those used at the Meyer Mill. The two centrifugals at the Meyer Mill are nearly identical in design -- one has a narrower molasses spout than the other. One centrifugal is reinforced with seven metal braces wrapped around the outer bucket. The braces would have prevented the machine from flying apart under the strong vibration caused by the machine's operation.[105]

The Meyer Mill operation required steam power solely for driving the centrifugals; a small steam engine sufficed for this purpose. In May, 1879, to drive the centrifugals, Meyer purchased an Ames Iron Works No. 1 Portable Steam Engine and Boiler manufactured in Oswego, New York. H. Hackfeld & Co., which eventually became the agent to handle the Meyer Mill sugar account, provided the engine and boiler at a total cost of $687.59. The price included drayage, customs fees, marine insurance, freight charges, labor, and a 2.5% commission paid to the San Francisco supplier, possibly to the Benecia Agricultural Works on the upper part of the San Francisco Bay.[106]

The Ames Iron Works No. 1 Portable Steam Engine was a simple, single cylinder, horizontal, reciprocating engine with a bore of 5" and a stroke of 10". When operating at its rated capacity of 6 horsepower the engine turned at 175 revolutions per minute. Even though the engine carried a separate 24" diamater belt wheel with a 5" face, the belt from the engine to the countershaft ran off of the engine's 40" diameter flywheel with its 6" face.

Steam came from the boiler thorugh a steam pipe and passed through a throttle valve into the steam chest. A slide valve operated by an eccentric on the engine's shaft alternately opened and closed the ports on the steam chest, admitting steam to one side or the other of the cylinder. When the slide valve uncovered a port the steam on the other side of the piston escaped into the exhaust pipe. The forward and backward motion of the piston in the cylinder, reciprocating motion, was transmitted by the piston rod, to the cross-head, through the wrist pin and the connecting rod to the crank where the piston's reciprocating motion was altered to the rotary motion of, the shaft, flywheel, countershaft, pulleys, and finally the centrifugal. Although the cylinder was very small it was cast separately and bolted to the engine frame.[107]

A small belt ran from a pulley on the engine's shaft to a pulley which drove a ball-type governor. The governor operated as a feed-back loop which monitored the engine speed and kept it fairly constant. Unlike engine governors which regulated valve timing and thus the amount of steam entering the cylinder from the steam chest, the Ames engine's governor regulated the amount of steam received from the boiler through the throttle valve. If the engine started to race excessively, the rotating governor balls would fly outward from their equilibrium position, depressing a small valve stem which would in turn close the throttle valve, admitting less steam to the steam chest and cylinder. Receiving less steam the engine slowed down. If the engine suddenly slowed down the governor balls would fall, lifting a small valve stem which would admit more steam to the steam chest and cylinder.

The Ames No. Portable Steam Engine was designed so the exhaust steam from the engine could be used to heat the boiler's feed-water before it

entered the boiler. After leaving the engine's cylinder, exhaust steam entered a 4 1/4"x2 1/2" exhaust steam chest running the length of the 5'5 1/2" engine frame base. The steam left the chest through a steam exhaust pipe on the shaft-end of the engine. Boiler feed water flowed through a loop in the exhaust steam chest, entering and leaving the chest on the cylinder end of the frame. The arrangement was such that the steam passing around the feed water pipes raised the temperature of the feed water. A small water pump, connected to and powered by the steam engine's piston rod, pumped water up from the feed-water clarifying cistern, through the loop in the exhaust steam chest, and into the boiler. The arrangement for heating the feed water resulted in increasing the capacity of the boiler and conserving fuel at almost no cost. Using hot feed water also reduced the wear on the boiler by removing the temperature extremes between cold feed-water and the water boiling to produce steam; such temperature differences would strain the boiler by producing unequal expansion and contraction of its iron parts.[108]

Meyer not only heated the boiler feed-water; he also neutralized corrosive acids in the water by treating it before it entered the boiler. The boiler received its water through pipes Meyer laid out on his land in 1876 from a spring. The water was piped through the Boiling House where it could be used for cleaning purposes. The water then entered a feed-water cistern located between the steam engine and the boiler. Meyer apparently used litmus paper to test the acidity of the water. Caustic soda or soda ash was mixed with the water in the cistern to neutralize the acids which were present. The water was then pumped through the heater and into the boiler.[109]

The Ames Iron Works No. 1 Boiler provided steam for the Meyer Mill steam engine. It was a small locomotive-type fire-tube boiler. The boiler was

internally fired, the furnace, 34" long, 18" wide, and 26" high was surrounded by water. The walls of the furnace were made double, allowing for a water space between the inside shell of the furnace and the outside shell of the boiler. These water legs made up part of the heating surface of the boiler. Wood and probably some bagasse served as fuel.

The hot gasses from the fire in the furnace escaped by passing through one of twenty-two fire tubes, 2.25" in diameter and 61" long, which ran from the front, furance, end of the boiler to the back, smoke-chamber, end. The gasses then went up the smokestack. The barrel or shell of the boiler was a 24" in diameter, 84" long, cylindrical shell which contained the fire-tubes, surrounded by water, and a smoke-chamber at the end. As the hot gas passed through the fire tubes it heated the surrounding water and created the steam. The total area of interchange between the water and the hot gasses in the fire-tubes, the boilers heating surface, was about 66 square feet. The steam collected in the steam dome above the water line and when it reached the correct pressure, about 120 pounds, it moved from the boiler to the steam engine through the connecting steam pipe. The furnace-end of the boiler had gauges which monitored steam pressure and water level, which were adjusted by admitting more water and regulating the steam gauge. The boiler also carried a whistle and a safety valve which consisted of a weighted arm; when the steam pressure rose above the safe level, as represented by the weights on the weighted arm, the arm would be pushed up letting the steam out of the fluted column steam port on the furnace-end of the boiler.

Locomotive boilers, similar to the one used at the Meyer Mill, were only manufactured in small sizes and were intended primarily for use in isolated locations where only a small amount of power was required. Driving the 6

horsepower engine to run the centrifugals, only on the days when the sugar was actually being dried, the Ames engine and boiler combination was ideally suited to the limited power and steam requirements of the Meyer Mill.[110] Two heavy brackets 45" apart rest on top of the boiler's cylindrical barrel. These brackets were designed to anchor the steam engine directly on top of the boiler, making a very compact boiler-steam engine unit. At the Meyer Mill the boiler and steam engine were installed separately, each receiving its own wood, masonry, and Portland Cement foundation.[111]

Meyer constructed the various mill buildings out of standard pieces of lumber imported from the West Coast of the United States. The buildings were of light-weight truss construction, sided in redwood boards with structural floor, wall, and roof pieces constructed of northwest pine, 2"x4", 2"x6", 3"x4", 4"x4", and 4"x6". The Boiling House was 50' long and 30' wide. The Boiling House's entire south wall and 10' of the east wall, around the furnace, had a 4' deep masonry foundation. The sorghum pan flue and smoke-stack rested on a masonry platform in the southwest corner of the building. Five windows in the south wall and three in the north wall, as well as openings in the two end walls, admitted light to the Boiling House. The sills supporting the floor joists rested on spot foundations built up of boulders and Portland Cement. The entire floor was raised off of the ground by the spot foundations and a second floor was built below the main floor in the area over the Molasses Pits. Access to the Molasses Pits was gained by removing hatch doors in both of the floors. Judging from the record of all materials received for constructing the mill buildings, they appear to have been roofed with shingles.

A 10 1/2'x20' shed was originally built against the outside northwall the Boiling House at the northwest corner, abutting a masonry platform extending outside from the center of the north wall. In 1881, the shed was enlarged to run the entire length of the north side of the Boiling House and measured 50'x15'. The new structure was completed in connection with the purchase of six additional sugar coolers and probably served as a well ventilated, dry Cooling Shed for granulating the sugar.

The Engine and Boiler House, 20'x25', runs along the west wall fo the Cooling Shed and part of the west wall of the Boiling House. The Engine and Boiler House appear to have been altered and expanded in 1881 at the time that the Cooling Shed was enlarged. Access to the Boiler and Engine House was through doors in the southwest corner and through a door in the north wall by the boiler.[112]

In the 1870s and 1880s, the Meyer Mill with its $7,000-$8,000 investment, was somewhat of an anomaly in the technically advancing and high capitalized Hawaiian sugar industry; an industry in which capitalists, such as Claus Spreckels, were consolidating control of cane production and marketing, and investing upwards of $2,000,000 in idnividual sugar mills. Meyer marked a transition in Hawaiian agriculture from its older diversified, subsistence, and small farm base to a cash crop plantation base. Meyer had experimented with numerous crops in part to support his large family and in part to earn some outside income from agriculture.

The cultivation of thirty acres of cane fit well within the pattern of previous experiment on the family land. Another side of Meyer, the public official and man of affairs, also may have affected his decision to enter into sugar cane cultivation. Meyer started growing cane in 1876, the year of the Reciprocity Treaty between the United States and Hawaii. In later years Meyers

corresponded with Charles Reed Bishop, one of Hawaii's leading businessmen and the owner of the large cattle ranch on Molokai's west end which Meyer managed; they frequently discussed business conditions in Hawaii, the price of sugar, and the politics underlying the Reciprocity Treaty.[113] It is conceivable that Meyer introduced sugar into his agricultural business to be a part of the events of the day -- Reciprocity and the expansion of Hawaiian sugar cultivation.

The late 1870s were a time of unbridled optimism concerning the possibility of profitable sugar cultivation even on a small scale; in 1876 the Hawaiian Gazette reported, "We believe there is a most admirable opportunity presented here of testing the policy of sugar culture by small farmers . . . An industrious man with a family of boys, or the assistance of two or three hired men, and a half a dozen mules, could easily plant and cultivate twenty acres of cane a year . . . leaving a margin for clear profit [of $1,000-$2,000], which we may safely assert is obtainable nowhere else in the world from arming of equal scope."[114] The San Francisco Chronicle reported in 1877 that news from Honolulu indicated that "The desire to engage in the cultivation of sugar cane has become a perfect furor, and that clerks, professional men, and in fact individuals of almost every class are turning their attention to an industry which has made the fortunes of those engaged in it . . .The main cause of this sudden access of prosperity is the reciprocity treaty."[115]

Even though Molokai, as generally viewed in 1875, lacked the large well-watered tracts suitable for large sugar estates such as existed on other islands in Hawaii, it was perceived as suitable for limited sugar cultivation. In 1875, Henry M. Whitney reported that on Molokai, "There are several small but fertile valleys . . .where sugar cane and ramie will thrive, and where

small plantations will probably be commenced."[116] In 1877, after inspecting samples of cane grown on Kamaloo Plantation on Molokai, the Commercial Advertiser reported, "We are glad to learn that the prospects of cane growers on Molokai are quite flattering."[117] A few months later the same paper declared, "the neighboring island of Molokai . . . has indeed been neglected in the past, but is now coming to the foreground, as possessing large tracts of fine cane land to be improved, and moreover some excellent harbors."[118]

R.W. Meyer was aware of and attempted to aid in the development of sugar cultivation on Molokai even before the signing of the Reciprocity Treaty. He viewed internal improvements as a foundation fo further agricultural development, particularly of crops, sugar, and cattle raised for export. In 1874, Meyer wrote to H.T. Wideman, Minister of Interior, lobbying for the release of money appropriated for road improvements; he wrote, "There is a prospect of two sugar plantations being started on this island and for that purpose it will be necessary to widen the roads to permit the use of carts which requires in many places considerable labor and expenditure."[119] In subsequent years Meyer complained that road improvements were concentrated on Molokai's east end and neglected the "nearly impassable state of the cartroad between Kalai and Kaunakakai."[120] Meyer frequently lobbied the Interior Department for road improvements in the neighborhood of his plantation and Charles R. Bishop's cattle ranch, pointing out that the majority of the District's road taxes were raised in these areas. Meyer started to cultivate sugar in 1876 when the prevailing assessment of the chances for successful and profitable cultivation was good.

The results of the first year's work at the Meyer Mill apparently justified the public optimism and Meyer's personal investment in sugar production on Molokai. The Mill started full operation in January, 1880, and while no systematic record survives of the Mill's sugar receipts, it clearly made a good profit. In the first six months of 1880, Meyer produced 19,191 pounds of raw sugar. Eighty-five to one hundred pounds of sugar were placed in separate bags and shipped by inter-island steamer to H. Hackfeld & Co. in Honolulu. Acting as the sugar agent, Hackfeld handled the majority of the Meyer sugar and generally shipped it on to California refineries. Hackfeld also purchased the molasses by-product which was sent to Honolulu in wood barrels.[121] In general, however, molasses was not of major market importance. When a good price was paid for sugar, molasses and rum were of little concern to the Hawaiian sugar industry.[122] For the 19,191 pounds of sugar, Hackfeld paid Meyer $1,759.52. The Meyer Mill expenses for this same period amounted to $723.77. If Meyer continued to receive the same price for his sugar in the second half of 1880, about .09 per pound, he would have made $3,166 for the 34,794 pounds of raw sugar he produced. Thus, in 1880, with the total operating expenses of $1,395.56, the Meyer Mill produced 53,985 pounds of sugar, receiving approximately $4,925 from Hackfeld, which left a $3,529 profit after the first year of operation.[123]

The surviving expense account book for the Meyer Mill does not include any item which calculated a price for, or compensated, Meyer, his son Otto who had chief responsibility for the Mill, or any of the children for their labor at the Mill; therefore, the expense account does not reflect the true costs of the family's involvement in the sugar business. The accounts do record every item purchased for the cultivation and manufacture of the sugar.

They also record the cost of all hired labor used in the Mill and the fields. Unlike most Hawaiian sugar plantations of the 1870s, which relied on a large number of immigrant laborers to work in the fields and the mills, Meyer hired a few men and these appear to have been local Hawaiians. In 1880, for example, Meyer employed, farily steadily, Kale, Kauluna, and Kakapu; they were paid $8, $4, and $4 respectively each month. Meyer also gave the hired men poi, meat, and salmon which cost him $11-$12 per month. These three workers all received a $2 per month raise in pay in 1881. Meyer also recruited Hawaiian day laborers at $.75 per day during a particularly busy harvest season. In April, 1883, Meyer considered contracting 4 to 6 Chinese workers to work at the plantation and mill for $8 per month.[124] In May, 1883, apparently dismissing the idea of hiring Chinese, Otto Meyer wrote his father, "I'm afraid we cannot build the house for the Chinamen now but I think those men we have hired will do for sometime."[125] In 1885 Meyer contracted with the Immigration Board of the Department of the Interior and hired a thirteen-year-old Portuguese boy, Joseph Correa, to work for $6.50 a month at the mill; this contract appears to be the only case where Meyer hired immigrants to work on his plantation. It might have been less expensive for Meyer to hire occasional day laborers because there are several months recorded in which the Mill had no expenses at all; this would not have been possible if Meyer signed long-term contracts with immigrant laborers.

Apparently encouraged by the results of the first year of operation, Meyer carried out several hundred dollars in improvements at the mill in 1881; he installed the second centrifugal at a cost of $350 along with its two pulleys, collars, and a new, larger, countershaft, all provided by the Honolulu Iron Works at a cost of $88.25. Meyer rebuilt the Cooling Shed and installed

6 sugar coolers which cost $40 each. A new smokestack was added to the boiler costing $43.25. Figures available for 1883 indicate that the Meyer Mill produced 33,226 pounds of sugar in 1883. If Meyer's sugar sold at the lowest prevailing market rates $.06 per pound for that year, a conservative estimate of the revenue would be that the Mill made $1,994. Despite lower sugar prices, sales amounting to $1,994 still represented a profit of $1042.52 since the Mill's operating expenses for 1883 totalled only $951.48. In 1884, the sugar price dropped and Meyer's produced only 31,209 pounds, with mill operating expenses of $716. In 1885, the Meyer Mill production rose to 57,476 pounds but he probably could not get much more than $.05 per pound, which would give $2,874 total revenues against $985.94 total expenses, leaving a $1,888 profit.[126]

Meyer did well enough in his first two years that in 1882 the Meyer Mill was featured in a Planter's Monthly article entitled "Small Sugar Mills." The author, W.E. Rowell, stated that as the large tracts of sugar land were taken up, agriculturists would do well to seek out smaller tracts for cane cultivation. Rowell argued that the smaller planters could profit more by building small sugar mills than by milling their cane on shares at a central factory; the planters could save on transportation cost, manage their labor more efficiently, and be assured by having the mill available when the cane was just ripe for milling. Rowell decalred, "A careful estimate of the costs of small plants . . . convinces me that many planters . . . could increase their net profits by putting up small mills and manufacturing for themselves . . . (I) have had my figures in regard to expense corroborated by Mr. Meyer, of Molokai, who kindly gave me the working results on his own

plantation. His experience is sufficient to establish the fact that a small mill can be worked economically."[127] Meyer's first years in operation appear to have justified his decision on the type of sugar processing technology and management necessary to make his "small sugar mill" profitable.

The sanguine hopes for profitable operation of small sugar mills expressed by Power, Meyer, and others, collapsed in the 1880s as the world price of raw sugar steadily declined. Although Meyer continued to operate at a marginal profit, at least through 1885, the last year for which reliable figures are available, the Mill does not appear to have ever produced at a profit as substantial as its first year of full operation, 1880, when the profit totalled about $3,500. In 1884 the Planters' Monthly decalred that the "enormous increase" in beet root sugar production had made sugar prices fall to such an extent that many plantations would do well just meeting expenses.[129] Adopting Darwinian metaphor and equating technical innovation with economic survival, none of which boded well for the Meyer Mill, the Planters' Monthly decalred that sugar production would survive only where it was conducted "upon the most advanced principles and the most economical methods. It will be a case of the survival of the fittest, and those who adhere to primitive methods, or even to only methods inferior to the best, will either be forced out of the market or will struggle along in a hand to mouth fashion, constantly on the verge of bankruptcy."[130] The journal declared that the low price made it "doubly necessary" to save on labor, fuel, and adopt machinery to extract more sugar from the cane.[131]

In 1886, J.M. Lydgate summed up the disappointing experience of many who, like Meyer, enthusiastically entered into sugar production in the period immediately following the Reciprocity Treaty. He wrote, "Many of us embarked

in the business 8 or 10 years ago with little or no experience and a faint conception of what we were undertaking, but with a positive glow of hope in the future before us. Now after these years we have the experience, a vivid recollection of what we have come through and the glow or at least most of it has faded out of the sky."[132] The low price of sugar in the early 1880s did not prove to be a temporary aberrfation; rather, it began to look as if it were a perma nent economic reality in the industry. In 1887 the Planters' Monthly continued to point toward a bleak future in the industry, "Low prices of sugar still previal, and remain low with discouraging persistency; so that the hopes we once entertained of seeing again the days of flourishing propserity fade out utterly into the dark, and many a man who once thought himself assured of reasonable wealth through sugar, now finds it will not even yield him a competence. Under existing conditions in Hawaii, as a whole sugar is not remunerative."[133]

The economic conditions prevailing in the Hawaiian sugar industry during the 1880s produced a business trend totally opposite from the direction W.E. Rowell had proposed, using the Meyer Mill as the leading example. Rather than the flourishing development of many small plantations operating their own small mills, like the Meyer Mill, sugar interests were rapidly consolidated in the 1880s with small holdings grouped into larger ones. The new plantations all depended on a technically advanced agricultural system including steam plowing and irrigation and technically sophisticated mill operations, including stronger three and then five roll mills, vacuum pans, double effects, and triple effects, and othertechnical improvements which made many Hawaiian mills "compare favorably with any of the best mills in the world."[134] The Planters' Monthly reported that the move towards large plantations and the latest, modern, factories was such that "if there is any money to be squeezed out of

cane, they are going to get it;" the journal concluded that "large concerns live where it would be utterly impossible for small concerns to eke out an existence, and so it is here and must be, that only running the sugar business on a large scale can it be made to pay."[135]

During this period of plantation consolidation, the closing of small mills, and small or nonexistent profits in the sugar business, the Meyer Mill ceased operation. Meyer appears to have operated the mill through 1888 and for at least part of 1889. The Molokai tax assessors' books indicate the Mill's closing. The Meyer Mill was built for $7,372.56, it was assess at $6,000 for 1882. The assessment for "Misini, ano a pau," machinery of all kinds was $2,500 for 1887, $2,000 for 1888, $600 for 1889, and $200 for 1890.[136] R.W. Meyer's sales account with H. Hackfeld & Co., account No. 21, received its last credit for sales on October 18, 1899.[137] For all of 1889 the Hackfeld Co. only credited Meyer with $629.78 in sales. The account may have included some other agricultural product; however, if the account was for sugar along, 1889 appeared to be a year in which Meyer clearly stopped earning any money from sugar production. In 1892 C.M. Hyde visited the Meyer Family at Kalae and reported, "Mr. Meyer and his sons raised sugar cane and manufactured sugar, but the low price of the product for the last few years has made it more than unprofitable to engage in sugar manufacture in a small way. Now lands are given up to grazing . . . cattle and sheep, butter and eggs are sent to Honolulu and lead the market as being always of the best grade."[138]

In visiting the Meyer Family, C.M. Hyde noted that the agricultural conditions at Kalae, and on Molokai in general, "would have discourage any man of less persistency of character (than Meyer). The lack of water (is)

one great drawback."[139] The lack of water and large arable tracts of land militated against Molokai's development as a sugar-producing or crop producing island.[140] This lack of crop forming and sugar production helped shape much of the Island's modern history. The other sugar mills on Molokai were forced to close along with the Meyer Sugar Mill in the 1880s and early 1890s. In 1887, with H. Hackfeld & Co. as agent, Eugene Bal & Co. started a sguar mill at Moanui, Island of Molokai, and in 1880 had 114 acres in cultivation with an estaimted annual yield of 250 tons. Fifty men worked at the Moanui Plantation which was valued at $60,000 and operated a mill with a capacity to grind 8 tons of cane per day.[141] Before 1883, Bal & Co. sold Moanui Plantation to Wong Leong & Co. and in 1885 the plantation was not considered very profitable.[142] In January, 1887 a fire destroyed the Moanui Mill. Charles R. Bishop who had a financial interest in the insurance on the mill reported to R.W. Meyer, "Sugar is low, and the prospects of that plantation were not very flattering before the fire."[143] In March, 1887, the mortgage on the Moanui Plantation was foreclosed.[144]

J. McColgan served as the agent for the Kamaloo Plantation which started on Molokai in 1887.[145] By 1880, Kamaloo had 100 acres under cultivation and also served as the mill for over thirty Hawaiians who raised from two to ten acres of cane independently.[146] The mill and plantation, managed by D. McCorriston employed 35 men in 1880 and was valued at $50,000.[147] In the late 1880s, the Kamaloo mill employed between 50 and 60 men, including in 1890, for example, 15 Hawaiians, 10 Chinese, 25 South Sea Islanders, 3 British, and 6 from other nationalities.[148] The mill closed in 1891 or 1892 and reopened, as the Kamaloo Sugar Company, for a few years between 1899 and 1901. The mill did not operate in 1902 and its closing marked the end of commercial sugar

production on Molokai. Despite the efforts to produce sugar at the Meyer, Moanui, and Kamaloo plantations, the weather, geography, and the economics of the Hawaiian sugar industry combined to bring failure to their attempts to establish sugar as a part of the Molokai economy. In 1882 Meyer, Moanui, and Kamaloo represented the three smallest sugar plantations operating in Hawaii.[149] Of the 39,350 acres of young cane, rattoons, and maturing sugar crops being grown throughout Hawaii, Molokai cultivated only 300 acres. To an annual harvest of 59,124 tons, Molokai's three plantations contributed 473 tons.[150]

On his 1892 visit to Molokai, C.M. Hyde pondered the arid island land and realized that if water could be brought to the rich, fertile land on Molokai's west end it would have a tremendous affect on the agriculture of the region. Hyde concluded, "If in the fissure between two lands . . . artesian wells could strike a water bearing stratum and bring water to the surface, the land that is not worth more than ten cents would be worth a hundred dollars an acre."[151] R.W. Meyer had worked toward this end when in 1884 and 1885, while managing Charles Reed Bishop's cattle ranch on Molokai's west end, he had laid down several miles of water pipe, dug water wells, and constructed windmills to pump water to the surface for the cattle. In 1898, under the agency of C. Brewer & Company, the American Sugar Company was established to turn 750 acres of Molokai's west end into a sugar plantation. By 1899 the American Sugar Company employed 559 men, 476 of whom were immigrant Japanese contract laborers, and had built a narrow gauge railroad, miles of irrigation ditch, and steam pumps of 10,000 gallons daily capacity to pump artesian well water to the sugar fields. The pumps soon started pumping brackish water to the surface which killed the cane and ended the only major attempt to establish large-scale sugar cultivation and production on Molokai. In the

summer of 1900 McBryde Sugar Company on Kauai purchased the mill which had been ordered for the American Sugar Company's Molokai plant.[152]

Had the American Sugar Company succeeded in raising sugar cane, or had the same success with bringing water to Molokai's west end as Meyer had, R.W. Meyer would be credited, in part with having pioneered an industry which without doubt would have changed Molokai's twentieth-century history. As it turned out, the major social, economic, and technical changes wrought by the Hawaiian sugar industry were left to other people and other islands. The American Sugar Company lost hundreds of thousands of dollars in their failed effort at sugar cultivation, and R.W. Meyer probably ended up earning a few thousand dollars from his investment in sugar.

NOTES:

Abbreviations used in Notes:
Rudolph Wilhelm Meyer: RWM
Otto S. Meyer: OSM
Planters' Monthly: PM
Hawaiian Gazette: HG
Pacific Commercial Advertiser: PCA

1. "Cheerful" Ship Manifest located at Hawaii State Archives, Honolulu, Island of Oahu, Hawaii.

2. Ibid.; C. M. Hyde, "Rambling Notes on Molokai," HG, 27 September 1892.

3. See for example, Department of the Interior Letter Book, Vol. 14, 27 February 1877, p. 149; RWM to H.A.P. Carter, 22 February 1886; Department of the Interior, Lighthouse File, RWM to J.H. Bayal, 30 December 1891; Hawaii State Archives, Honolulu, Island of Oahu, Hawaii.

4. C.M. Hyde, "A Visit to Molokai," HG, 16 September, 1885.

5. Molokai Tax Assessors Book, Hawaii State Archives, Honolulu, Island of Oahu, Hawaii.

6. Ibid., 1889.

7. Hyde, "Rambling Notes on Molokai," HG. 27 September, 1892.

8. For references to starting dates see OSM to RWM, 3 May 1876, 5 September 1876, in Meyer Family Papers, in collection of Alexander Meyer, Island of Molokai, Hawaii. Unless otherwise stated all Meyer correspondence is located in this collection.

9. R.D. Mead, "A History of the Progress of the Sugar Industry of Hawaii Since the Reciprocity Treaty of 1876," PM, 27 (December, 1908): p. 486-487.

10. "Ownership of Hawaiian Sugar Plantations," PM, 2 (November, 1882): p. 171.

11. George Bowser, The Hawaiian Kingdom Statistical and Commercial Directory and Tourists Guide, Honolulu, 1880, Part II, p. 410.

12. Hyde, "A Visit to Molokai," HG, 16 September 1885.

13. OSM to RWM, 12, 19 April, 18 May, 7 June, 6 September, 1883.

14. OSM to RWM, 2 February 1883.

15. OSM to RWM, 26 January 1883.

16. OSM to RWM, 19 April 1883.

17. OSM to RWM, 3 May 1883.

18. Judd & Detweiler, The Sugar Producing Capacity of the Hawaiian Islands, New York, 1881, unnumbered page.

19. OSM to RWM, 24 May 1883.

20. Hyde, "Rambling Notes on Molokai," HG, 27 September 1892.

21. Ibid.

22. OSM to RWM, 4 October 1883.

23. PM, (August 1, 1882): p. 104-105.

24. OSM to RWM, 3 May 1883.

25. OSM to RWM, 26 April 1883.

26. OSM to RWM, 19 June 1884.

27. Hyde, "A Visit to Molokai," HG, 16 September 1885; see also Blymyer Manufacturing Co. to RWM, 14 March 1877, Papers of R.W. Meyer Ltd., Kaunakakai, Island of Molokai, Hawaii.

28. See Ned Karker to Elsie H. Wilcox, 3 January 1952, Grove Farm Museum Collection, Lihue, Island of Kauai, Hawaii.

29. Wray, The Practical Sugar Planter, p. 329.

30. The gutter was recalled by Wilhelm G. and Ernest Meyer, July, 1978, Interview, Kalae, Island of Molokai, Hawaii.

31. OSM to RWM, 26 April, 3 May, 16 May, 1883.

32. Meyer Family Recollections, July, 1978; Mule Harness order in Sugar Mill Account Book, in Wilhelm C. Meyer Collection, Kalae, Island of Molokai, Hawaii; Horses and Working Mules are recorded in Molokai Tax Assessors Book, Hawaii State Archives, Honolulu, Island of Oahu, Hawaii.

33. See for example Thomas Kerr, A Practical Treatise On the Cultivation of Sugar Cane and the Manufacture of Sugar, London, 1851, p. 84; N.P. Burgh, A Treatise On Sugar Machinery, London, 1863, p. 2.

34. Today (1978) the Meyer Cane Mill remains in good condition. The drive shaft is no longer in a vertical position and instead lies next to the mill. Nearly all of the brass bearings on the drive shaft and the rolls are missing. Some timber bed plate has completely rotted away, leaving the mill on a slant, supported by the tie-down bolts which once anchored the mill into the bed plate. The mill rests in part on its juice tray obscuring the area where the cane juice drained from the juice tray into the gutter which ran to the Boiling House. The gutter itself is no longer present and the tunnel in the masonry mill enclosure through which it ran is choked with roots and soil. Four 2"x4" wooden braces extending from the sides of the circular mill area enclosure to the top of the mill frame are no longer in place. The booms which radiated from the top of the drive shaft to where the animals were attached to them are no longer in place. The area of the mill itself has been substantially overgrown -- the passageways leading to and from the mill appear to have been originally deeper. The two bridges over the passageways which permitted the animals to make a full circle around the top of the mill enclosure are no longer in place.

35. Lihue Plantation Invoice Book, Invoice # 21, 24 March 1850, Lihue Plantation Company Papers, Lihue, Island of Kauai, Hawaii; R. Armstrong, "Report On Machinery And Agricultural Implements," Royal Hawaiian Agricultural Society, Transactions, 2 (1854); pp. 93-95; "Agriculture of the Hawaiian Island," PCA, 2 April 1857.

36. Thomas Thrum, Hawaiian Annual, Honolulu, 1875, p. 39.

37. "Annual Review," PCA, 10 February 1866.

38. "Enclosure No. 3," The Friend, (March 18, 1867): p. 11.

39. Sugar-Cane, (July 1-3, 1871): p. 50.

40. Kerr, Treatise On the Cultivation of Sugar Cane, p. 81; Leon Wray, The Practical Sugar Planter, London, 1848, p.. 289-294.

41. Sugar Mill Account Book, Wilhelm C. Meyer Collection, Kalae, Island of Molokai, Hawaii. In June, 1878, before he ground any cane Meyer paid Capt. T.H. Hobron $20 for a "missing piece of Sugar Mill;" he also paid Mr. Hughes $380 "for repairing etc. Sugar Mill as per contract." (Sugar Mill account book, Wilhelm C. Meyer Collection, Kalae, Island of Molokai, Hawaii). T.H. Hobron was a Maui merchant and former sugar planter. The only Hughes listed in the 1880 Bowser directory of Hawaii and likely to have repaired the animal powered mill for the Meyer Plantation was Thomas Hughes, former manager of the Honolulu Iron Works and in 1880 the manager of the Hamakua Mill Company, owned by Theo. H. Davies and located on the Island of Hawaii. (PCA 3, July 1910, 12 March, 1922).

42. Blymyer Manufacturing Company to RWM, 14 March 1877, Papers of R.W. Meyer Ltd. Kaunakakai, Island of Molokai, Hawaii.

43. The records are not complete but the price range was determined from Sugar Mill Account Book, in Wilhelm C. Meyer Collection, Kalae, Island of Molokai, Hawaii, Hereafter referred to as "Sugar Mill Account Book."

44. Figure represents amount invested in Mill from January 1, 1876 December 31, 1879, just prior to the full operation of the Mill figures recorded in Sugar Mill Account Book.

45. Ralph S. Kuykendall, The Hawaiian Kingdom, 3 Vols., Honolulu, 1967, Vol. 3, pp. 72-73.

46. PCA, 2 April 1857.

47. "On Argicultrual Implements," Royal Hawaiian Agricultural Society, Transactions, 1(1951); p. 118-119.

48. HG, 18 December, 1878.

49. HG, 23 August 1882; PCA, 15 April 1882.

50. Bowser, The Hawaiian Kingdom Statistical and Commercial Directory, pp. 424-425.

51. Kerr, Treatise On the Cultivation of Sugar Cane, P. 103.

52. "Sugar Mill Account Book."

53. OSM to Rwm, 12 April 1883.

54. "Sugar Mill Account Book."

55. PCA, May 14, 1863.

56. Peter Soames, A Treatise on the Manufacture of Sugar From the Sugar Cane, London, 1872, p. 48.

57. The sacrometer measured density by the Beaume scale, OSM to RWM, 18 May, 20 September, 1883.

58. Kerr, Treatise On the Cultivation of Sugar Cane, p. 310.

59. "Sugar Mill Account Book."

60. OSM to RWM, May 18 1883.

61. PCA, May 7, 1883.

62. PCA, April 16, 1863.

63. PCA, May 7, 1863.

64. Ibid.

65. Ibid.; PCA, April 16, 1863.

66. Ibid.

67. C. P. Judd to S. G. Wilder, 26, January 1864, Wilder Family Papers, Hawaiian Mission Childrens' Society Library, Honolulu, Island of Oahu, Hawaii. Unless otherwise specified the Judd and Wilders letters are all contained in the above collection.

68. G.P. Judd to S.C. Wilder, March 11, 1864.

69. "Convention of Sorghum Sugar Manufacture," Scientific American, (May 6-24, 1862): p. 329.

70. PCA, 2 January 1869.

71. H.A.P. Carter to S.C. Wilder, March 14, 1863.

72. William Reed, The History of Sugar and Sugar-Yielding Plants, and Epitome of Processes of Manufacture, London, 1866, p. 86.

73. Wray, The Practical Sugar Planter, p. 376.

74. Ibid., pp. 301-303, p. 376.

75. Ibid., p. 304-305, Soames, Treatise on the Manufacture of Sugar, pp. 45-48.

76. PCA, April 2, 1857.

77. PCA, October 22, 1877.

78. Kerr, Treatise On the Cultivation of Sugar Cane, p. 115; Wray, The Practical Sugar Planter, p. 305-306.

79. "Enclosure No. 3," The Friend, (March 18, 1867): p. 11.

80. PCA, Nott & Company advertisement, November 5, 1870; S.G. Wilder to G.P. Judd, May 17 1864; Isavella L. Bird, Six Months in the Sandwich Islands, 1875; Honolulu, 1966, p. 77.

81. Today (1978) some major parts of the Meyer Mill boiling apparatus are no longer in place. The two copper clarifiers have been removed. They most likely occupied the entire 10' x 5' space at the head of the sorghum pan. They probably operated as a first and second stage clarifier, with the cane juice passing through and being limed in clarifier and then on to the next before flowing to the first compartment of the sorghum pan. Rivets or screws appear to have connected the second clarifier to the sorghum pan. The furnace grate bars have been removed, as has much of the fire brick which lined the furnace and flue letting the sorghum pan sit compactly on the flue; this tight-fitting arrangment kept the furnace and smoke from escaping into the Boiling House. Parts of the masonry flue wall itself have deteriorated. The smokestack has been removed and its masonry base has deteriorated to such an extent that the precise form, place, and connection between the flue and the smokestack, and between the smokestack and the Boiling House itself, cannot be reconstructed. The sorghum pan remains in good condition; the last compartment is missing part of its Redwood siding. All of the handlevered sluice gates which regulated the flow of juice from one compartment to the next are missing.

82. OSM to RWM, May 11, 1883.

83. OSM to RWM, April 5, 1883.

84. H.A.P. Carter to S.G. Wilder, March 14, 1863; Evans, Sugar Planters' Manual, P. 164.

85. Kerr, Treatise On the Cultivation of Sugar Cane, p. 136.

86. The sugar cooler was recalled by Wilhelm C. and Ernest Meyer, Interview, July 1978.

87. OSM to RWM, July 24, 1884.

88. Soames, Treatise on the Manufacture of Sugar, p. 77; "On the Manufacture of Sugar Cane, Sugar-Cane, (May 1-5, 1873): p. 242.

89. Henry M. Whitney, A Brief Sketch of the Early History and Growth of the Sugar Industry In Hawaii, Honolulu, 1876. p. 5.

90. H.A. Peirce & Company to Royal Hawaiian Agricultural Society, August 13, 1851, in RHAS, Transactions, I(1851): p. 118-119.

91. "Fanny Major" Ship Manifest from San Francisco, May 10, 1853, located in Hawaii State Archives, Honolulu, Island of Oahu, Hawaii.

92. Royal Hawaiian Agricultural Society, Transcations, 1(1853): p. 4.

93. PCA, April 2, 1857.

94. Geo. W. Wilfong, "Twenty Years' Expertise In Cane Culture," PM, 1(October, 1882): p. 146-152.

95. "Report of the Committee on Sugar," Royal Hawaiian Agricultural Society, Transactions, 2(1854): p. 17-18.

96. See the Honolulu Iron Works letterhead in Sugar Plantation Papers, Hamilton Library, University of Hawaii, Honolulu, Island of Oahu Hawaii; see also advertisements for: F.T. Lenehan & Company PCA, March 3, 1877; George Gray, MacFarlane & Company, PCA, May 14, 1877; Theo J. Davies, PCA, September 7, 1878; Honolulu Iron Works, HG, August 13, 1877; Castle & Cook, HG, October 29, 1879, June 16, 1880.

97. D.M. Weston to Castle & Cook, 8 April 1880, Corporation Papers, Hawaii State Archives, Honolulu, Island of Oahu, Hawaii.

98. Soames, Treatise on the Manufacture of Sugar, pp. 83-85; "On the Manufacture of Sugar From the Sugar Cane," Sugar-Cane, 5(1 May 1873): p. 244.

99. Soames, Treatise on the Manufacture of Sugar, p. 85.

100. Honolulu Iron Works to Theo. H. Davis Esq., October 7, 1881, price quoted for 4 Weston Patent Centrifugals, iron framing, and countershaft for Lidgate & Company mill was $4,300, Sugar Plantation Papers, Hamilton Library, University of Hawaii, Honolulu, Island of Oahu, Hawaii.

101. "On the Manufacture of Sugar From Sugar Cane" Sugar-Cane, 5(1 May 1873): p. 242.

102. G. P. Judd to S. G. Wilder, March 31, 1864.

103. "Newfangled Equipment of the Other Days Now "Antiques', "Honolulu Advertiser, Paril 2, 1934.

104. Ibid.

105. Today (1978) the two centrifugals are in excellent condition. Parts of the wooden clutch are missing and the fast and loose pulleys for one centrifugal are missing from the steam engine's countershaft. The 4" belts which connected the countershaft pulleys with the centrifugals' pulleys are also missing.

106. T.T. Waterman, "Old Sugar Mill Still Stands On Molokai; Needs Only Mule," Honolulul Advertiser, April 23, 1934.

107. Thomas T. Eyre, Engines and Boilers, New York, 1922, pp. 78-82.

108. E.M. Shealy, Steam Boilers, New York, 1912, pp. 303-331; Henry De Berkeley Parsons, Steam Boilers Their Theory and Design, New York, pp. 256-263.

109. E.M. Shealy, Steam Boilers, New York, 1912, pp. 294-296.

110. Ibid., p. 11.

111. Today (1978) the boiler and steam engine at the Meyer Mill remain in very good and nearly complete condition. Several brass oil cups and a brass bearing are missing from the steam engine. The governor balls have been removed but not lost. Some of the steam pipe joints and fittings are missing. On the boiler the steam and water gauges are missing and rust has corroded nearly all of the boiler's fire tubes. The smokestack is also missing from the boiler. Given the nearly ninety years of idleness the boiler and steam engine exist in a remarkably good state of preservation.

112. Today (1978) the mill buildings housing the machinery and sugar processing equipment at the Meyer Mill have deteriorated substantially. Little remains of the Boiling House floor structure, or its two end walls. Some Redwood boards and the sill which supported them are missing from the south wall. Some of the posts sorrounding the roof trusses are missing; however, the trusses themselves and the north wall, protected by the Cooling Shed, remain intact. Sections of the floor and the walls in the Cooling Shed are missing. Very littel remains of the Engine and Boiler House structure -- the sides, roof, and floor are all collapsed and in an advanced stage of rotting. Some time after 1886 the entire Boiling House and Cooling Shed received a corrugated roof which remains intact today. Aside for the Engine and Boiler House, and despite the missing sections of the various buildings, it is still possible to see and understand the simple structure, construction, scale, and general layout of the mill buildings as they existed when the Meyer Mill was in operation.

113. Charles R. Bishop to RWM, April 5, 1886.

114. "Development of Our Resources," HG, December 13, 1876.

115. San Francisco Chronicle, July 2, 1877.

116. Henry M. Whitney, The Hawaiian Guide Book for Travelers, Honolulu, 1875, pp. 59-60.

117. PAC, July 14, 1877.

118. PAC, September 8, 1877.

119. RWM to H.T. Wideman, 30 March 1874, Department of the Interior, "Roads: Molokai and Lanai, 1856-1876" File, Hawaii State Archives, Honolulu, Island of Oahu, Hawaii.

120. Ibid., RWM to S.G. Wilder, 16, 28, August 1878; RWM to H.A. Hassinger, June 25, 1881; RWM to G.T. Gulick, March 11, 1884.

121. OSM to RWM, April 19, 1883.

122. PAC, March 6, 1875.

123. "Sugar Mill Account Book."

124. OSM to RWM, April 19, 1883.

125. OSM to RWM, May 3, 1883.

126. Average sugar prices in Willett & Gray, Weekly Statistical Sugar Trade Journal, 16(29 December 1892): p. 3-4.

127. W.E. Rowell, "Small Mills," PM, 1(June 1882): p. 52-55.

128.

129. "Items," PM. 3(May 1884): p. 404; "The Sugar Future of the Islands," PM, 3(October 1884): p. 503-504.

130. Ibid., p. 503.

131. Ibid.; "Report of Committee On Machinery," PM, 3(November 1884): p. 553-556, p. 562-564.

132. J.M. Lydgate, "Why The Sugar Business Does Not Pay," PM, 5(September 1886): p. 152.

133. "Future of Cane Planting," PM, 6(July 1887): p. 292.

134. "Improvements in Sugar Mills At the Islands,: PM, 5(April 1886): p. 21-24.

135. "Editorial and General," Planters' Monthly, 6(July 1887): p. 392.

136. Molokai Tac Assessors Book, 1870.

137. H. Hackfeld & Company Ledger Books, Vol. 22A, 23A, 24A, H. Hackfeld Papers, Bernise P. Bishop Museum, Honolulu, Island of Oahu, Hawaii.

138. Hyde, "Rambling Notes On Molokai, HG, 27 September 1892.

139. Ibid.

140. Vernon G. Bottenfield, "Changing Patterns of Land Utilization on Molokai," M.A. Thesis, University of Hawaii, Honolulu, Island of Oahu, Hawaii, February, 1958; Charles R. Bishop, to RWM, March 22, May 3, 1884.

141. "Ownership of Hawaiian Sugar Plantations," PM, 2(November 1883); p. 171; Bowser, The Hawaiian Kingdom Statistical and Commercial Directory, p. 410.

142. Hyde, "A Visit to Molokai," HG, September 16, 1885.

143. Charles R. Bishop, to RWM January 31, 1887.

144. Charles R. Bishop, to RWM, March 28, 1887.

145. HG, March 7, 1877.

146. Bowser, The Hawaiian Kingdom Statistical and Commercial Directory, p. 411.

147. "Ownership of Hawaiian Sugar Plantations," PM, 2(November 1883); p. 171.

148. "Report of the President of the Board of Immigration to the Legislative Assembly of 1890," Hawaii State Archives, Honolulu, Island of Oahu, Hawaii.

149. "Ownership of Hawaiian Sugar Plantations," PM, 2(November 1883): P. 171.

150. "Report of Committee On Sugar Cultivation," PM, 1(November 1882): p. 198-205: Henry M. Whitney, "Cultivation and Yield of Sugar Cane in Hawaii," PM, 2(December, 1883): p. 269.

151. Hyde, "Rambling Notes On Molokai," HG, September 27, 1892.

152. "Report of the President of the Board of Immigration to the Legislative Assembly of 1898, 1899," Hawaii State Archives, Honolulu, Island of Oahu, Hawaii.